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PARTICLE INITIATED FOV OF HYBRID CYLINDRICAL INSULATING SPACERS UNDER AC AND DC VOLTAGES IN AIR FOR DIFFERENT ELECTRIC FIELD CONFIGURATION - AN EXPERIMENTAL APPROACH

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ABSTRACT

The ever – increasing voltage levels in electrical power systems need to enhance the power distribution and transmission system. The insulation failure is mainly due to the high voltage stress. The dielectric strength of air is greatly influenced by the presence of insulating surfaces. In the present research work the new hybrid cylindrical insulating spacers such as PMMA – PP, PP – NYLON and NYLON – PMMA and the orientation of hybrid cylindrical insulating spacers has been studied. The flashover performances are carried out experimentally in air as insulating media for different electrode configuration such as uniform electric field (Plane – Plane), non-uniform electric field (Needle – Plane) and moderately non-uniform electric field (Hemisphere rod – Plane) under AC and DC voltages. The effect of conducting floating particles is also carried out for different electrode configuration under AC and DC voltages. The experimental investigations shows that NYLON – PP and NYLON – PMMA hybrid spacers has highest flashover voltage (FOV) under AC voltages, in case of DC voltages PP – NYLON hybrid spacer gives highest FOV. The hybrid spacer PP – NYLON has more effective under AC voltage, whereas in case of DC voltage PMMA – NYLON has more effective with conducting floating particles.

Key words: PMMA (Polymethyl Methacrylic), PP (Poly Propylene), NYLON, FOV (Flashover Voltage), HV (High Voltage), LV (Low Voltage), T (Top), B (Bottom).

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1. INTRODUCTION

The performance of high voltage equipment mainly depends on the withstand voltage of insulating materials. The insulating materials have to work in extreme conditions, which demand high quality insulating materials with good electrical properties [1]. The steadily increasing demand for electric power, which leading to rapid increase in the area of electrical instruments and insulating materials [2]. The future development of power systems depends on the progress in insulating materials. Hence, a new generation of power system requires novel growth in the field of insulating materials [3]. The dielectric strength of air is greatly influenced by the presence of insulating materials in conventional air insulated systems. Surface discharge appear from the contact point between insulators and components under high voltage stress, constitute possible cause for insulation failure. Therefore, the flashover mechanism has been subject of numerous research work [4]. The electric field distribution with different electrodes such as pointed electrode, plane electrode, sphere electrode, rod electrode and rogouski electrode with common plate electrode as the bottom electrode are used for the breakdown voltages [5]. The conductors are to be essentially supported by solid insulators called 'Spacers' in high voltage equipment. Hence, it needs to search for the new hybrid cylindrical insulating spacers such as PMMA – PP, PP – NYLON and NYLON – PMMA as shown in Figure 1.

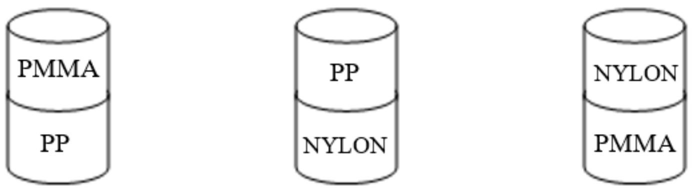

Figure 1. Hybrid Cylindrical Insulating Spacers

In this paper, the surface flashover performance of hybrid cylindrical insulating spacers for different electrode configuration such as uniform (plane - Plane), moderately non-uniform (hemisphere - plane) and non-uniform (needle - plane) fields in air under AC and DC voltages have been studied. The work is also carried out to study the effect of floating particles.

2. EXPERIMENTAL SETUP

The experimental setup to carry the flashover characteristics is as shown in Figure 2. The insulating spacer is placed tightly between the HV and LV electrode. The high voltage is applied by varying the auto-transformer, the voltage is gradually increased at an approximate rate of 1kV/sec till the flashover occurs along the surface of the spacer and voltage applied is recorded. The experiment is carried out for 5 trials and average value is calculated.

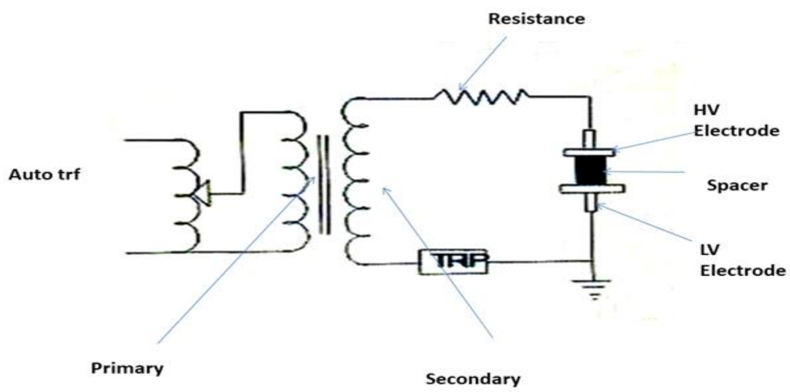

Figure 2. Experimental Setup for Measurement of FOV

This procedure is repeated for different hybrid insulating spacers for different electrode configuration under AC and DC voltages without and with conducting floating particles.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1. Without Conducting Particles

To study the flashover performance of combination of insulating spacers which have different dielectric properties, different resistivity and different dielectric constant are carried out under AC and DC voltages for different electrode configuration. The effect of orientation of the hybrid cylindrical spacers are also studied.

Table 1 FOV of Hybrid Cylindrical Spacers for Plane – Plane Electrode Configuration under AC Voltage (kV) Peak

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	PP(T) + PMMA(B)	PP(T) + NYLON(B)	NYLON(T) + PP(B)	NYLON (T) + PMMA(B)	PMMA(T) + NYLON (B)
Average	32.8	32.5	24.1	24.2	25.8	25.4

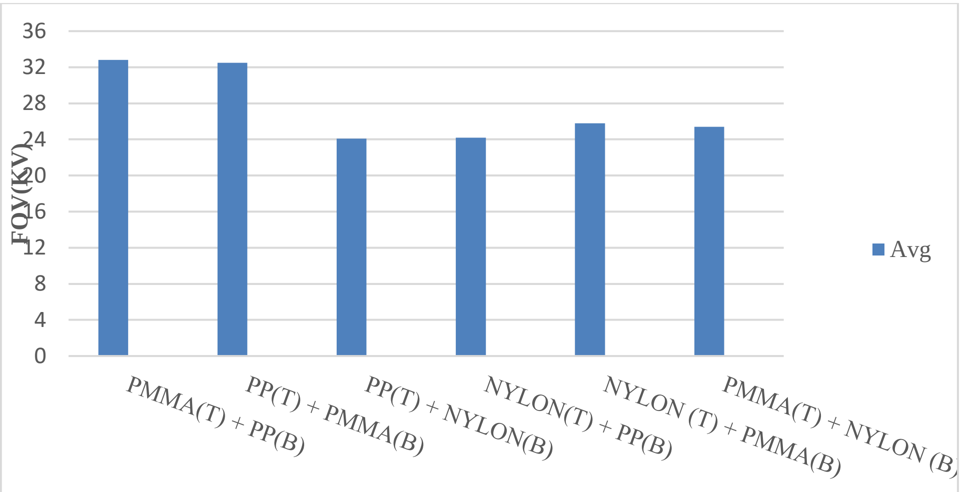

Figure 3 Flashover Characteristic of Hybrid Cylindrical Spacers for Plane – Plane Electrode Configuration under AC Voltage (kV) Peak

(a) The experimental values obtained for FOV with plane - plane electrode configuration, the hybrid cylindrical spacer PMMA – PP is observed an increase in average value is 27% compared to PP – NYLON and 21% compared to PMMA – NYLON. When the hybrid spacer is reversed, the PP – PMMA has highest FOV compared to NYLON – PP by 26% and PMMA – NYLON by 22% in average value under AC voltages are given in the Table 1 and the flashover characteristics shown in Figure 3.

Table 2. Flashover Voltage of Hybrid Cylindrical Spacers for Needle – Plane Electrode Configuration under AC Voltage (kV) Peak

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	PP(T) + PMMA(B)	PP(T) + NYLON(B)	NYLON(T) + PP(B)	NYLON (T) + PMMA(B)	PMMA(T) + NYLON (B)
Average	32.4	30.2	29.6	31	31.1	31.1

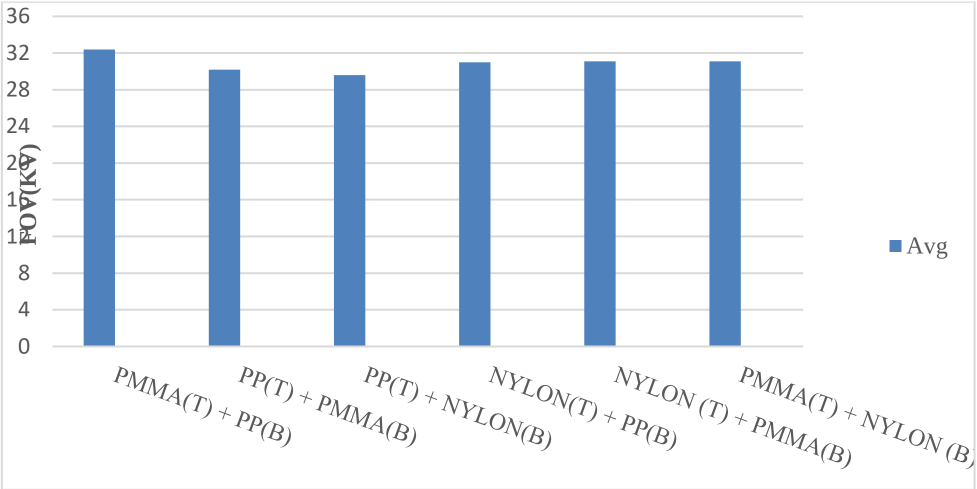

Figure 4. Flashover Characteristic of Hybrid Spacer for Needle – Plane Electrode Configuration under AC (kV) Peak

(b) In case of needle – plane electrode configuration under AC voltages the hybrid spacer PMMA – PP has highest FOV in average value compared to NYLON – PMMA by 4% and PP – NYLON by 9%. When the hybrid spacer is inverted, NYLON – PP, PMMA – NYLON and PP – PMMA gives almost same FOV average value is as shown in Table 2 and Figure 4.

(c) Table 3 and Figure 5 shows the results of FOV characteristics across hybrid spacers for hemisphere rod – plane electrode configuration.

Table 3 Flashover Voltage of Hybrid Spacer for Hemisphere rod - Plane Electrode Configuration under AC Voltage (kV) Peak

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	PP(T) + PMMA(B)	PP(T) + NYLON(B)	NYLON(T) + PP(B)	NYLON (T) + PMMA(B)	PMMA(T) + NYLON (B)
Average	30.8	29.6	30.8	28.9	29.7	31.1

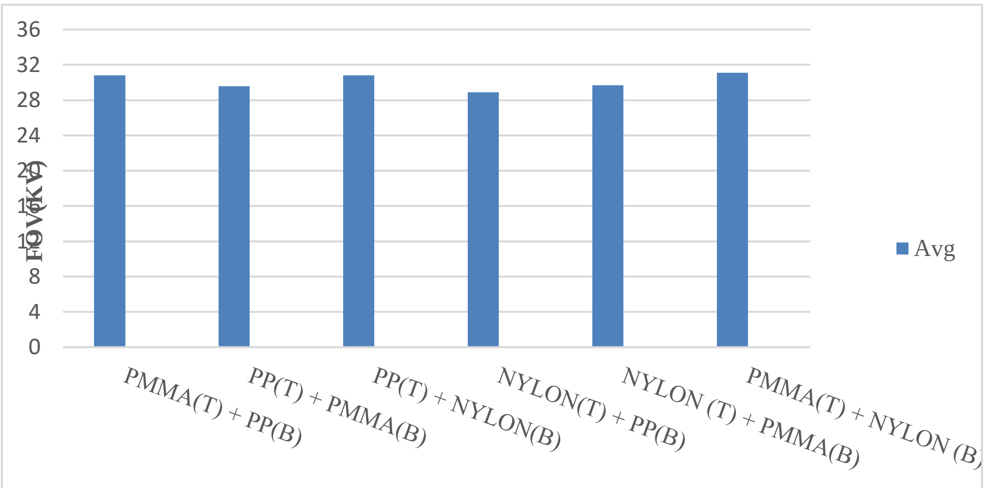

Figure 5. Flashover Characteristic of Hybrid Spacer for Hemisphere rod - Plane Electrode Configuration under AC (kV) Peak

The hybrid spacers PMMA – PP and PP – NYLON has shown the same FOV compared to NYLON – PMMA hybrid spacer. When the hybrid spacer is reversed, it observed that slight increase in average FOV value of PMMA – NYLON spacer compared to PP – PMMA and NYLON – PP spacers.

(d) The results of FOV values for hybrid spacer for plane – plane electrode configuration under DC voltages is shown in Figure 6 and values are given in Table 4.

Table 4. Flashover Voltage of Hybrid Spacers for Plane – Plane Electrode Configuration under DC Voltage (kV)

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	**PP(T) + PMMA(B)**	**PP(T) + NYLON(B)**	**NYLON(T) + PP(B)**	**NYLON (T) + PMMA(B)**	**PMMA(T) + NYLON (B)**
Average	23.1	16.8	31.1	22.1	21.6	25.3

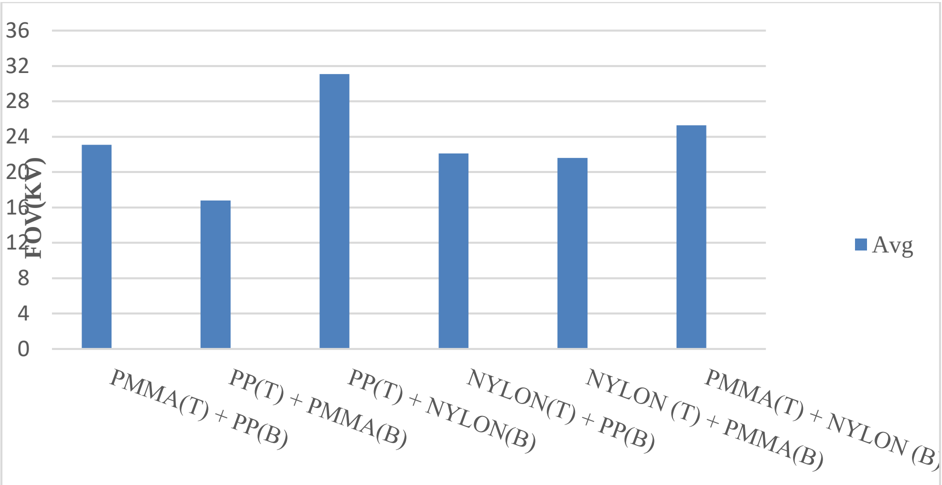

Figure 6. Flashover Characteristic of Hybrid Spacers for Plane – Plane Electrode Configuration under DC Voltage (kV)

From Figure 6, it is observed that the hybrid spacer PMMA – PP shows 26% less compared to PP – NYLON and 6% more in average FOV value compared to NYLON - PMMA hybrid spacer. When the hybrid spacer is reversed there is a decrease in FOV average value is observed in case of PP – PMMA and NYLON – PP by 34% and 13% respectively compared to PMMA – NYLON.

(e) The results obtained in case of needle – plane electrode configuration under DC voltages are shown in Table 5 and Figure 7.

Table 5. Flashover Voltage of Hybrid Spacers for Needle - Plane Electrode Configuration under DC Voltage (kV)

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	**PP(T) + PMMA(B)**	**PP(T) + NYLON(B)**	**NYLON(T) + PP(B)**	**NYLON (T) + PMMA(B)**	**PMMA(T) + NYLON (B)**
Average	26.5	24.2	38.5	30.6	33	33

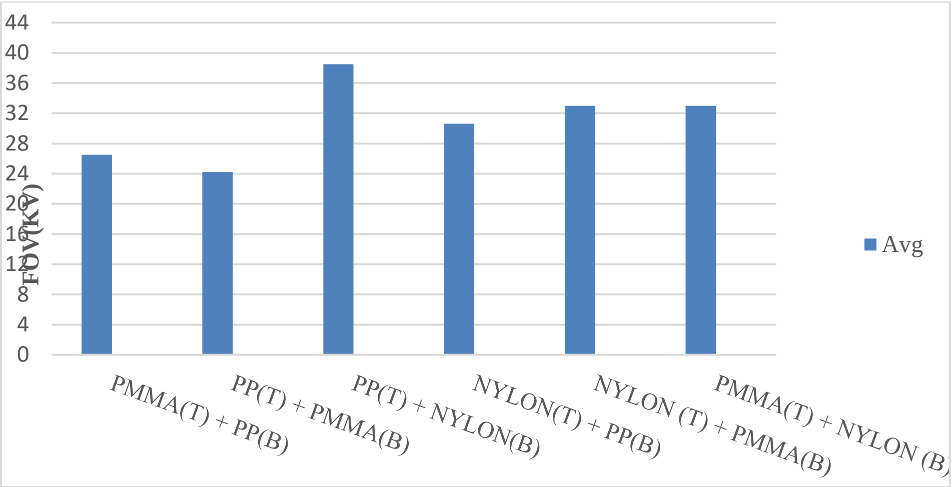

Figure 7. Flashover Characteristic of Hybrid Spacers for Needle - Plane Electrode Configuration under DC Voltage (kV)

From Figure 7, the PP – NYLON shows highest FOV compared to NYLON – PMMA by 14% and PMMA – PP by 31% in average value. When the hybrid spacer is reversed, PMAA – NYLON has higher average FOV value compared to NYLON – PP by 7% and 27% compared to PP – PMMA.

(f) The obtained FOV values are given in Table 6 and there FOV characteristics shown in Figure 8.

Table 6. Flashover Voltage of Hybrid Cylindrical for Hemisphere rod – Plane Electrode Configuration under DC Voltage (kV)

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	PP(T) + PMMA(B)	PP(T) + NYLON(B)	NYLON(T) + PP(B)	NYLON (T) + PMMA(B)	PMMA(T) + NYLON (B)
Average	26.7	32	38.2	29.2	34.6	31.3

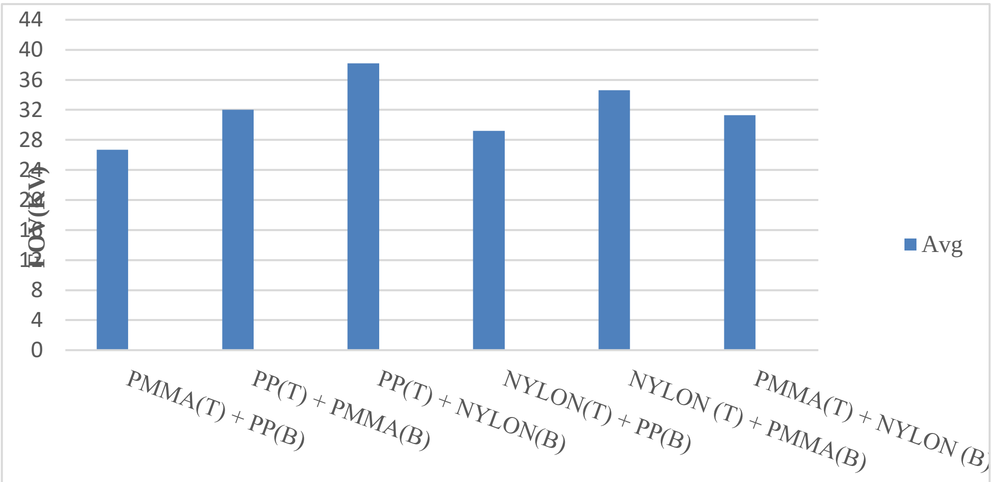

Figure 8. Flashover Characteristic of Hybrid Spacers for Hemisphere rod – Plane Electrode Configuration under DC Voltage (kV)

It is observed from Figure 8 that, there is a reduction in FOV average value of PMMA – PP and NYLON – PMMA compared to PP – NYLON by 30% and 9% respectively for hemisphere rod – plane electrode configuration. In case of orientation of hybrid spacer, PP – PMMA and

PMMA – NYLON hybrid spacer gives almost same FOV average value and there is reduction of FOV average value in NYLON – PP spacer.

3.2. With Conducting Particles

The effect of conducting floating particles has been studied for different electrode configuration under AC and DC voltages.

(a) The experimental values are shown in Table 7 and the corresponding FOV characteristics across hybrid cylindrical spacer consists of PMMA – PP for plane – plane electrode configuration under AC voltage with floating particles is shown in Figure 9.

Table 7. Flashover Voltage of Hybrid Cylindrical Spacers for Plane – Plane Electrode Configuration under AC Voltage (kV) Peak with Floating Particles

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	**PP(T) + PMMA(B)**	**PP(T) + NYLON(B)**	**NYLON(T) + PP(B)**	**NYLON (T) + PMMA(B)**	**PMMA(T) + NYLON (B)**
Average	13.6	16.2	20.8	14.6	14.3	14.3

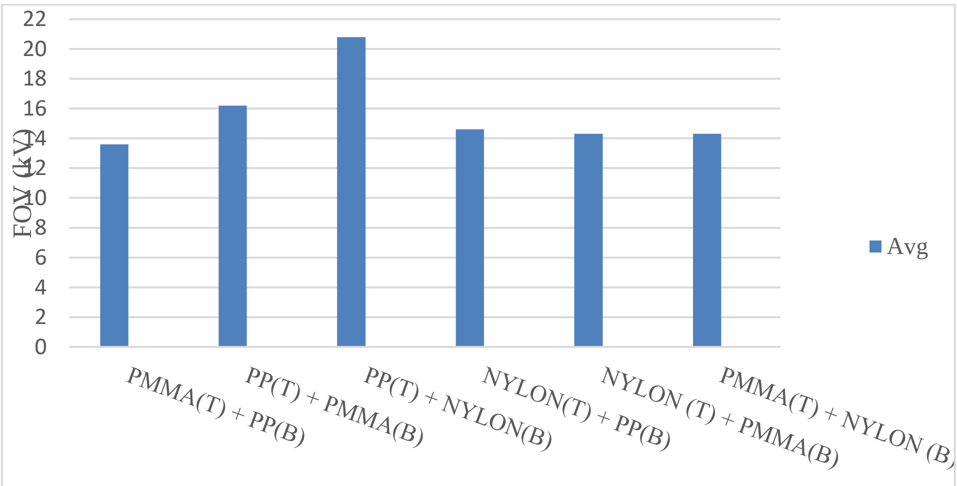

Figure 9. Flashover Characteristic of Hybrid Spacers for Plane – Plane Electrode Configuration under AC Voltage (kV) Peak with Floating Particles

The effect of floating is seen to be maximum extent in case of PP – NYLON and less in case of PMMA – PP compared to NYLON – PMMA. When the hybrid spacer is reversed the effect is more in case of PP – PMMA and less in case of NYLON – PP and PMMA – NYLON.

(b) It is observed from Table 8 that PP – NYLON has highest FOV average value compared to NYLON – PMMA by 21% and compared to PMMA – PP by 27%.

Table 8. Flashover Voltage of Hybrid Cylindrical Spacers for Needle – Plane Electrode Configuration under AC Voltage (kV) Peak with Floating Particles

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	**PP(T) + PMMA(B)**	**PP(T) + NYLON(B)**	**NYLON(T) + PP(B)**	**NYLON (T) + PMMA(B)**	**PMMA(T) + NYLON (B)**
Average	13.2	14.6	18.2	15.2	14.4	19.8

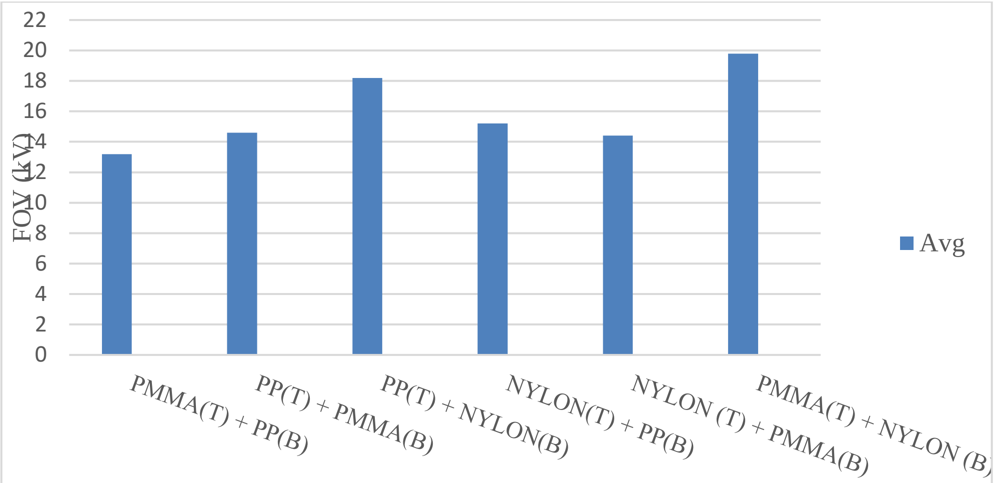

Figure 10. Flashover Characteristic of Hybrid Spacers for Needle – Plane Electrode Configuration under AC Voltage (kV) Peak with Floating Particles

When the hybrid spacer is reversed the effect is same in case of PP – PMMA and NYLON – PP and the effect is more in case of PMMA – NYLON as shown in Figure 10 for needle – plane electrode configuration with floating particles.

Table 9. Flashover Voltage of Hybrid Cylindrical Spacers for Hemisphere rod – Plane Electrode Configuration under AC Voltage (kV) Peak with Floating Particles

Voltage level	**FOV (kV)**					
	PMMA(T) + PP(B)	**PP(T) + PMMA(B)**	**PP(T) + NYLON(B)**	**NYLON(T) + PP(B)**	**NYLON (T) + PMMA(B)**	**PMMA(T) + NYLON (B)**
Average	12.7	14.8	18.6	15.2	15.1	16.9

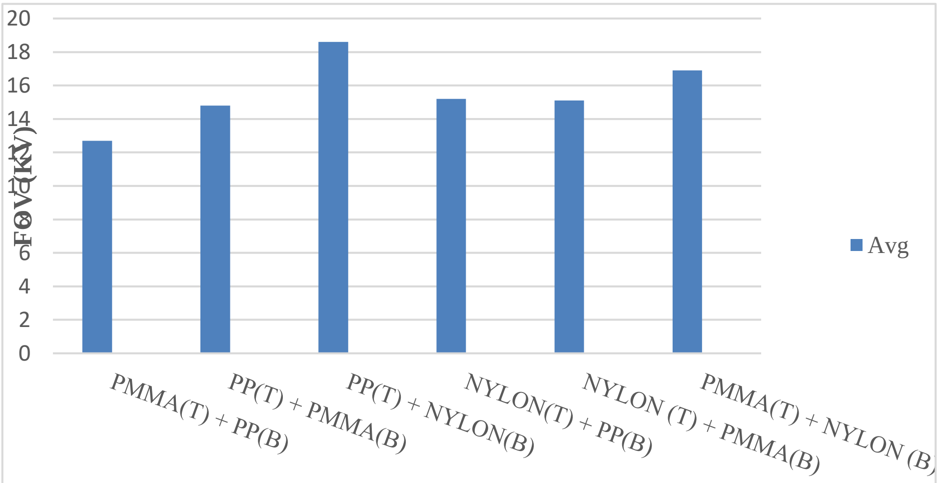

Figure 11. Flashover Characteristic of Hybrid Spacers for Hemisphere rod – Plane Electrode Configuration under AC Voltage (kV) Peak with Floating Particles

(c) In case of hemisphere rod – plane electrode configuration under AC voltage with floating particles. PP – NYLON is more effective compared to NYLON – PMMA and PMMA – PP combination. When the hybrid spacer is reversed the hybrid spacer PMMA – NYLON is more effective compared to other hybrid spacers combinations are given in Table 9 and the FOV characteristics shown in Figure 11.

Table 10. Flashover Voltage of Hybrid Cylindrical Spacers for Plane – Plane Electrode Configuration under DC Voltage (kV) with Floating Particles

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	**PP(T) + PMMA(B)**	**PP(T) + NYLON(B)**	**NYLON(T) + PP(B)**	**NYLON (T) + PMMA(B)**	**PMMA(T) + NYLON (B)**
Average	16.4	18.4	16.1	11	12.6	20.9

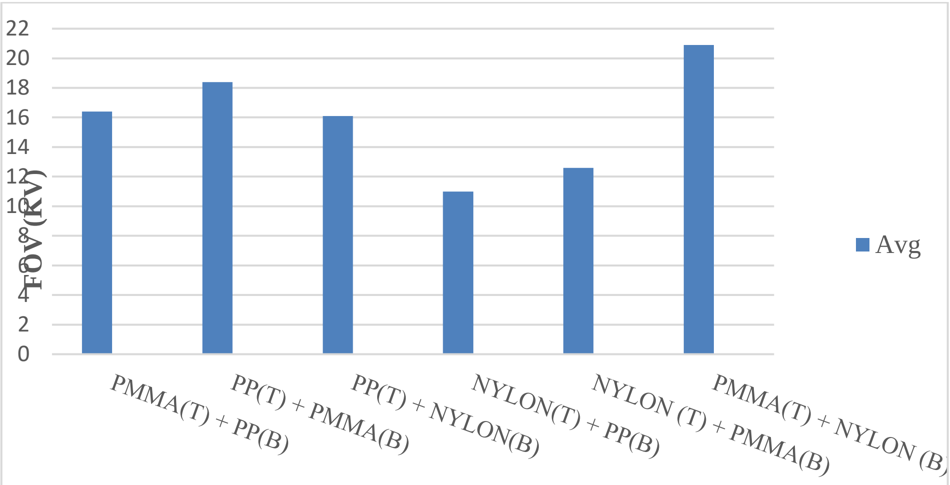

Figure 12. Flashover Characteristic of Hybrid Spacers for Plane – Plane Electrode Configuration under DC Voltage (kV) with Floating Particles

(d) Under DC voltage with floating particles for plane – plane electrode configuration, it is observed that PMMA – PP hybrid spacer is more effective followed by PP – NNLON and NYLON – PMMA. In case of orientation of the hybrid spacers PP – PMMA and PMMA – NYLON has more effective and NYLON – PP shows less effective as recorded in Table 10 and characteristics shown in Figure 12.

(e) In case of needle - plane electrode configuration with floating particles the FOV values are given in Table 11 and FOV characteristics shown in Figure 13.

Table 11. Flashover Voltage of Hybrid Cylindrical Spacers for Needle – Plane Electrode Configuration under DC Voltage (kV) with Floating Particles

Voltage level	FOV (kV)					
	PMMA(T) + PP(B)	**PP(T) + PMMA(B)**	**PP(T) + NYLON(B)**	**NYLON(T) + PP(B)**	**NYLON (T) + PMMA(B)**	**PMMA(T) + NYLON (B)**
Average	15.8	16.4	15.8	14.6	14.4	15.8

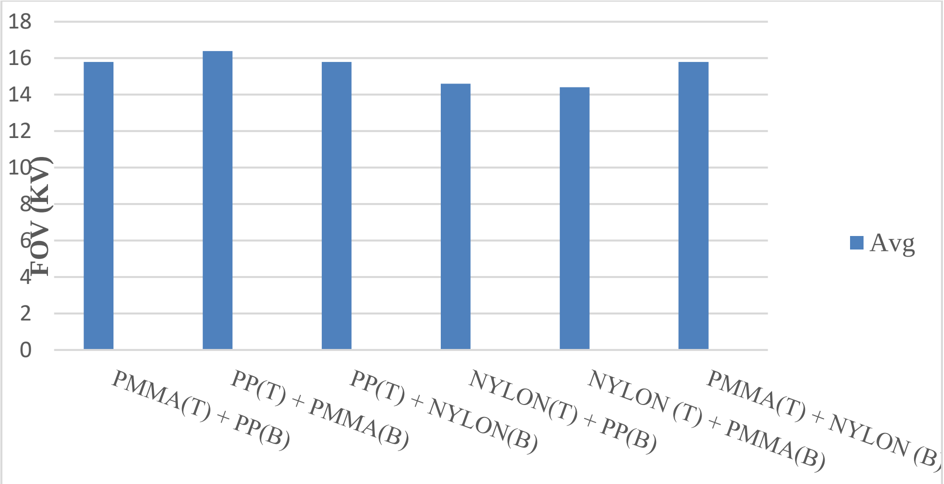

Figure 13. Flashover Characteristic of Hybrid Spacers for Needle – Plane Electrode Configuration under DC Voltage (kV) with Floating Particles

It is observed that from Figure 13, PMMA – PP and PP – NYLON hybrid spacer shows more effective compared to NYLON – PMMA. When the hybrid spacer is reversed PP – PMMA shows more effective compared to PMMA – NYLON and NYLON – PP.

Table 12. Flashover Voltage of Hybrid Cylindrical Spacers for Hemisphere rod – Plane Electrode Configuration under DC Voltage (kV) with Floating Particles

Voltage level	**FOV (kV)**					
	PMMA(T) + PP(B)	**PP(T) + PMMA(B)**	**PP(T) + NYLON(B)**	**NYLON(T) + PP(B)**	**NYLON (T) + PMMA(B)**	**PMMA(T) + NYLON (B)**
Average	17.5	16.4	17.3	13.6	14	18.3

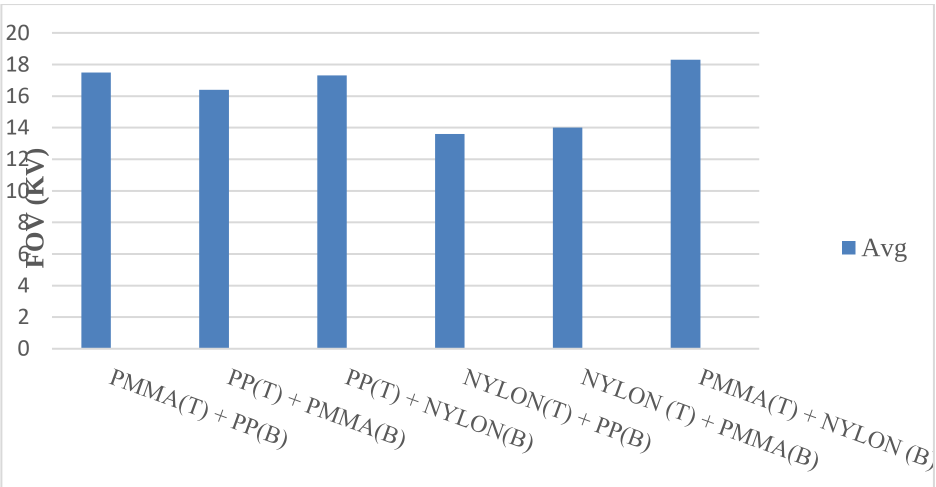

Figure 14. Flashover Characteristic of Hybrid Spacers for Hemisphere rod – Plane Electrode Configuration under DC Voltage (kV) with Floating Particles

(f) The FOV of hybrid spacers for hemisphere rod – plane electrode configuration with floating particles given in Table 12 and the FOV characteristics shown in Figure 14, it is observed that PP – NYLON and PMMA – PP has the same effect compared to NYLON – PMMA is less effective by 20%. In case of hybrid spacer orientation, it is observed that PMMA – NYLON has more effective than PP – PMMA and NYLON – PP by 10% and 26% respectively.

4. CONCLUSION

The experimental investigations carried out leads to the following conclusions:

Without Conducting Particles

- Under AC voltages, the PMMA – PP and PP – PMMA is observed highest FOV for plane – plane electrode configuration and in case of needle – plane electrode configuration NYLON – PMMA and PMMA – PP shows highest FOV, whereas in case hemisphere rod – plane PMMA – PP and PMMA – NYLON has highest FOV.
- In case of plane – plane electrode configuration under DC voltages, PP – NYLON and PMMA – NYLON shows better FOV and in case of needle – plane electrode configuration PP – NYLON and PMMA – NYLON spacers show better FOV, whereas in case of hemisphere rod – plane electrode configuration NYLON – PMMA and PP – NYLON shows better FOV.

With Conducting Particles

- Under AC voltages, the hybrid spacer PP – NYLON and PP – PMMA seen to be more effective in case of plane – plane electrode configuration and PP – NYLON and PMMA – NYLON is more effective in case of needle – plane electrode configuration, whereas in case of hemisphere rod – plane PP – NYLON shows more effective.
- Under DC voltages, PMMA – PP and PMMA – NYLON is more effective in case of plane – plane electrode configuration and PP – PMMA has more effective in case of needle – plane electrode configuration whereas in case of hemisphere rod – plane PMMA – PP and PMMA – NYLON shows more effective.

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